GAP PROGRAM OVERVIEW

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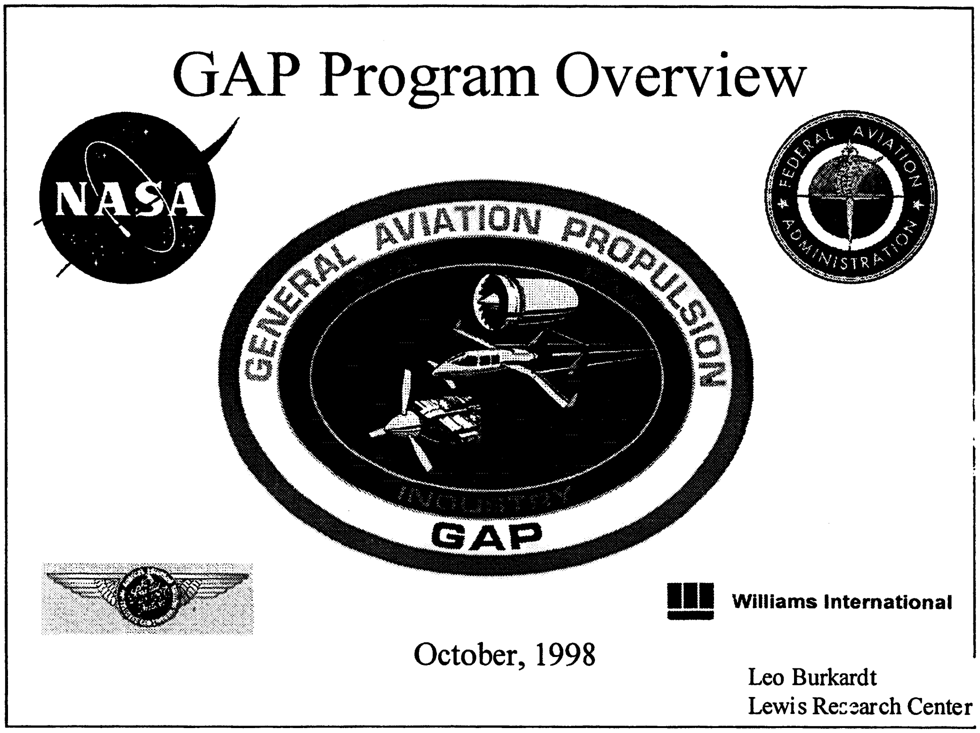
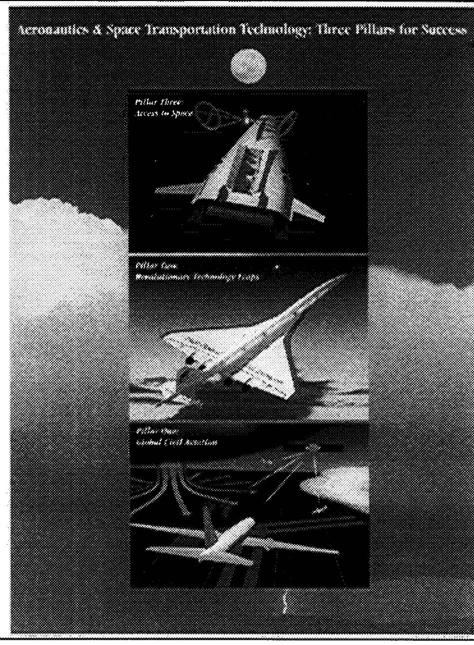


NASA's General Aviation Propulsion (GAP) program is a cooperative program between government and industry.

General Aviation Propulsion Program



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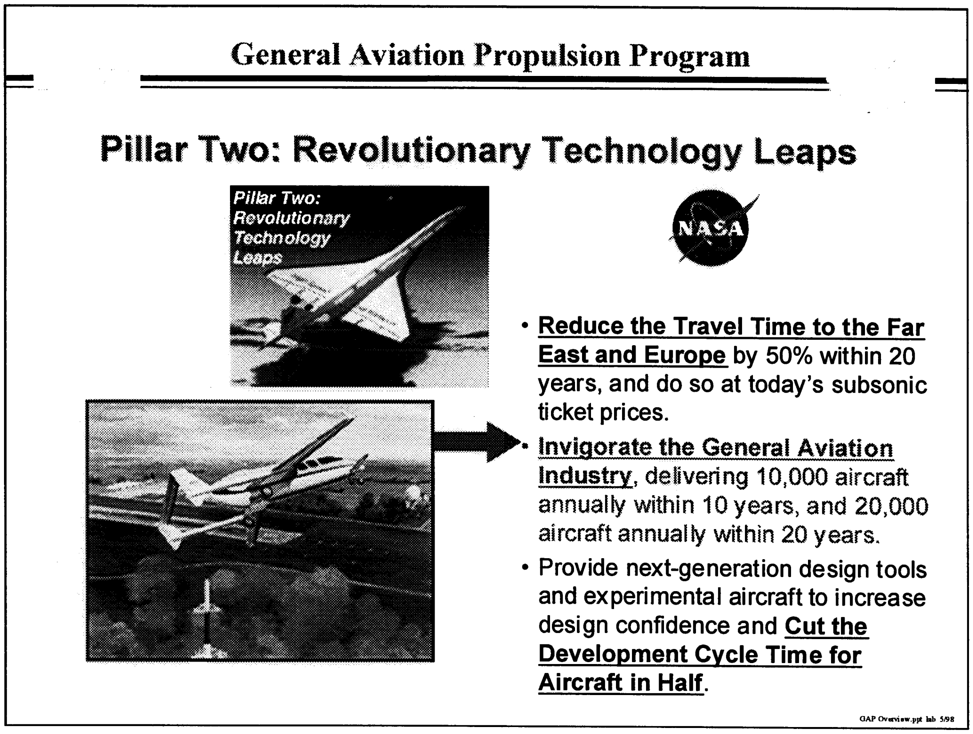
NASA's strategic direction is described by the "Three Pillars" and their Objectives as set forth by NASA Administrator Daniel S. Goldin. NASA's Three Pillars are: 1) Global Civil Aviation, 2) Revolutionary Technology Leaps, 3) Access To Space.



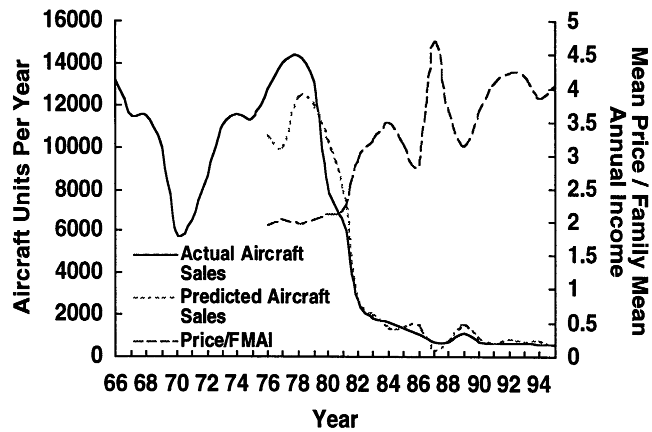
General aviation has fallen far behind in technology and affordability, therefore NASA's has included general aviation technology development under Pillar Two, Revolutionary Technology Leaps. The enabling technology Objective is: Invigorate the general aviation industry, delivering 10,000 aircraft annually within 10 years, and 20,000 aircraft annually within 20 years.

Putting NASA's goal in perspective, it means developing technologies that will once more enable general aviation manufacturers to produce aircraft that are attractive and affordable to the public. Though the production numbers stated in the Three Pillars Objective may seem fantastic compared to today's production levels, they really are stating nothint more than we would like to get back to the production level which general aviation once enjoyed before the "big crash" of the 80s. Before 1980 the sales trend for general aviation aircraft generally followed the gross national product.

With the average age of the current general aviation light aircraft fleet being approximately 30 years and the basic technology level incorporated into those aircraft being much older than that, the market is ripe for rejuvenation.

General Aviation Propulsion Program

Predicted vs Actual Piston Aircraft Sales



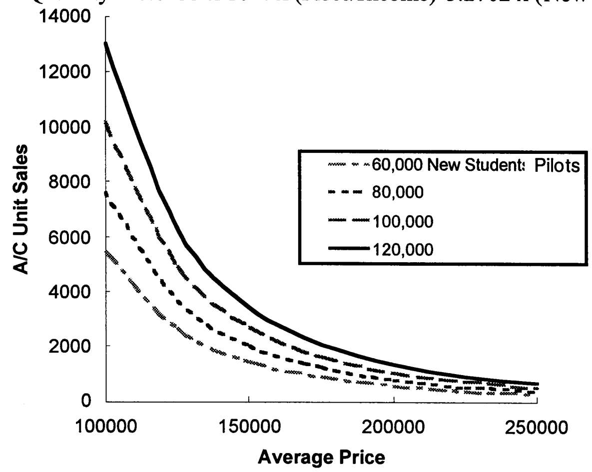
This chart shows the history of the general aviation market for the last 30 years. The market was able to recover from the first down turn in the late 60s but it essentially crashed after the down turn in the late 70s. As can be seen from the plot of aircraft price vs. family income, it was at the same time as the second down turn that aircraft price began to escalate dramatically. The obvious conclusion is that the rise in aircraft price played a big part in preventing a recovery in the market in the 80s and has kept the market at its very depressed levels ever since. The red line is a plot of an equation which was developed to represent the market history since the mid 70s. This equation is based on aircraft price and the number of pilots available to buy aircraft. It can also be used as a market demand model to assess the impact of GAP engine technologies on the market place based solely on the technologies effect on engine price. Engine performance and ease of use are not factored in to the equation, so predictions based on this equation should be conservative, that is, predict a smaller impact on aircraft sales than would be expected if performance and ease of use were also considered.

General Aviation Propulsion Program

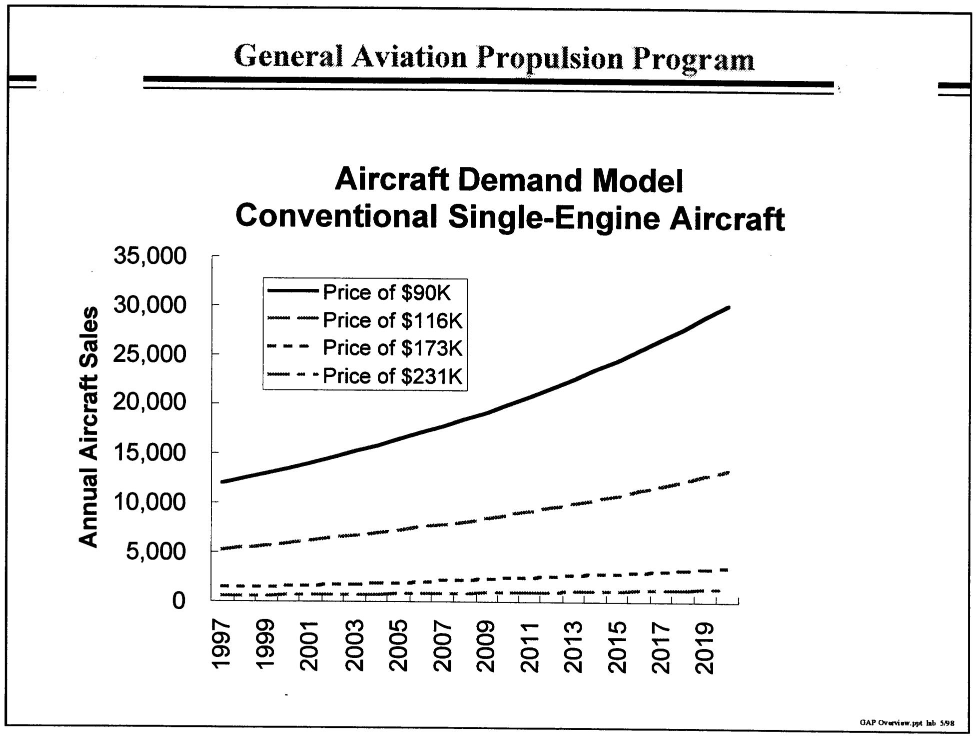
Aircraft Demand Model

(Evaluated at $55,000 Mean Income)

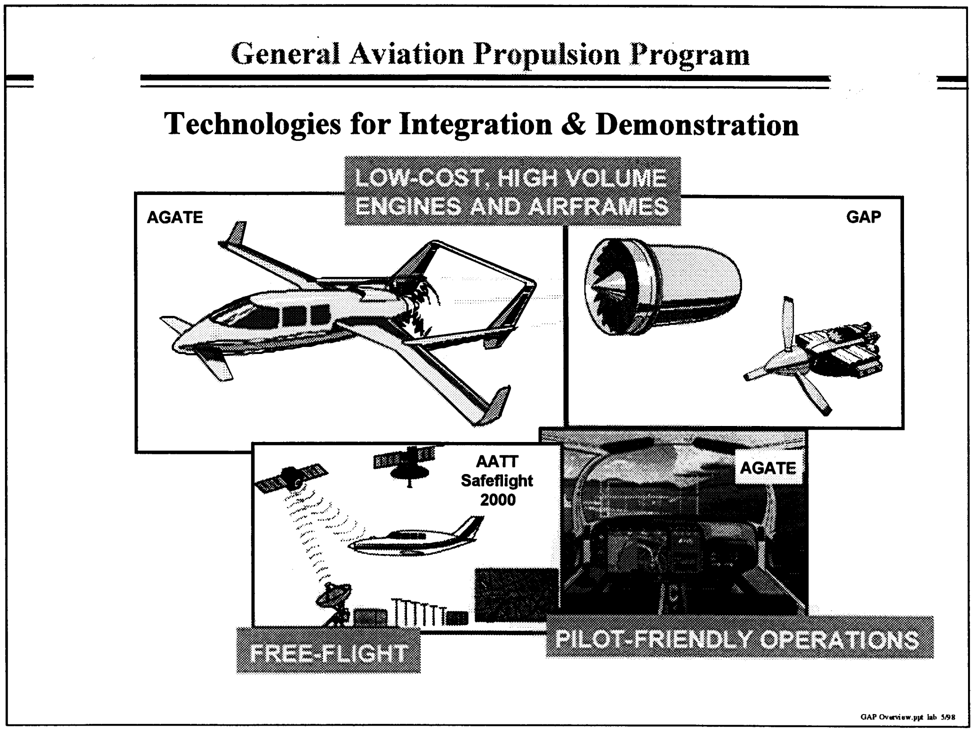
Quantity = 0.6433 x 10-4 x (Price/Income)-3.2702 x (New Pilots)1.9503



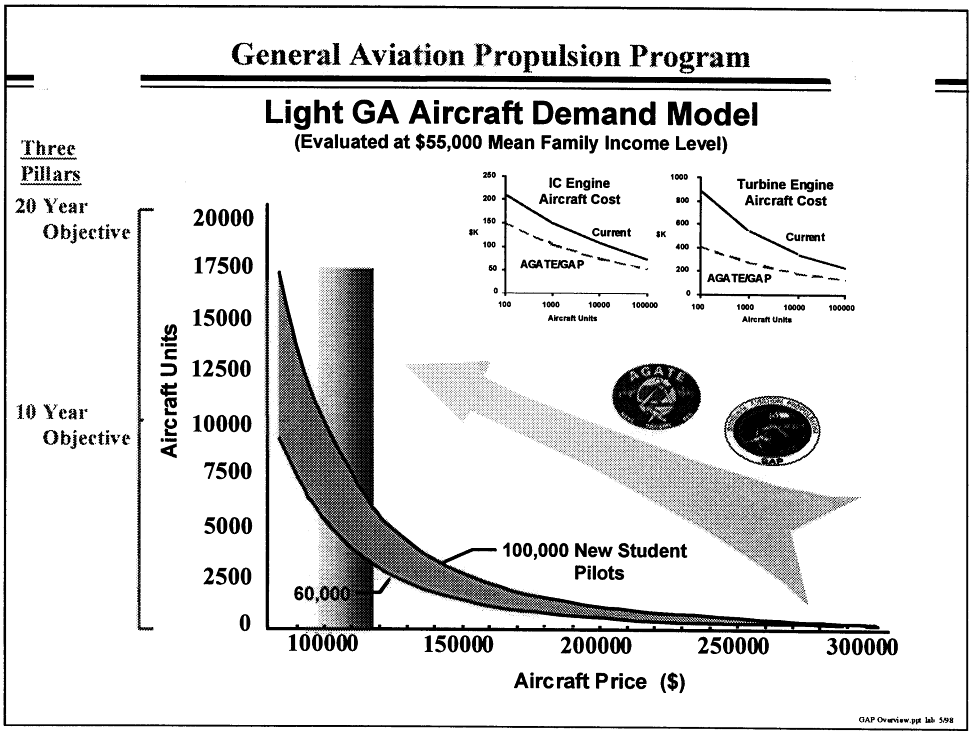
Using the market demand model developed from previous general aviation market history the effect of aircraft price on sales of aircraft can be predicted. The four lines represent different assumptions for the number of new pilots who would be potential buyers for an aircraft.



Assuming we start out with 100,000 new pilots in the first year with additional new pilots coming in to the market every year after that, this chart shows how many aircraft of various price levels might be sold on a yearly basis. Replacement of current aircraft is not included in this scenario, it assumes that only new pilots who don't yet own an aircraft would be buying the new aircraft. The number of new pilots each year is based on the goals of current general aviation industry pilot recruitment promotional efforts.

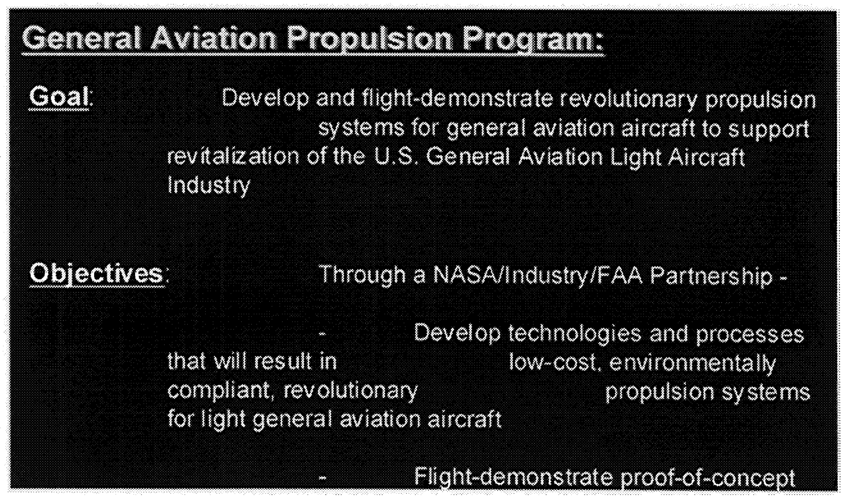


NASA, the FAA and the general aviation industry are all cooperating in trying to bring about the resurgence of general aviation. NASA has programs aimed at meeting the technology needs of the total general aviation market place and infrastructure. The two programs specifically aimed at general aviation are the Advanced General Aviation Transport Experiments (AGATE) program and the General Aviation Propulsion (GAP) program. AGATE is developing airframe and avionics technologies. GAP is concentrating on new engine development. Other NASA programs, while not specifically aimed at general aviation, have components which address the needs of general aviation. One such program is Advance Air Transportation Technology (AATT). This program is developing technologies for the air traffic control infrastructure which will increase safety, provide for greater numbers of aircraft and allow more aircraft freedom in routing and flight paths. General aviation is an important part of this air traffic picture.



Using engine price goals of the GAP program along with aircraft and avionics price goals of the AGATE program, which should enable the industry to sell a single engine 4 place aircraft for about $100,000, it looks as though the Three Pillars Objective of reaching a production rate of 10,000 aircraft per year in 10 years is within reach.

General Aviation Propulsion Program



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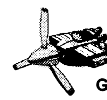
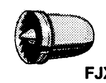
The General Aviation Propulsion program was established to address the technology needs of the general aviation engine industry. The specific goal of GAP is to develop and flight demonstrate revolutionary propulsion systems for general aviation aircraft to support revitalization of the U.S. General Aviation Light Aircraft Industry. This will be done in partnership with the FAA by developing technologies and processes that will result in low-cost, environmentally compliant, revolutionary propulsion systems for light general aviation aircraft. The major milestone of the program is to flight demonstrate fully manufacturable, certifiable propulsion systems in the year 2000 which meet or exceed the cost and operability requirements of the program.

General Aviation Propulsion Program

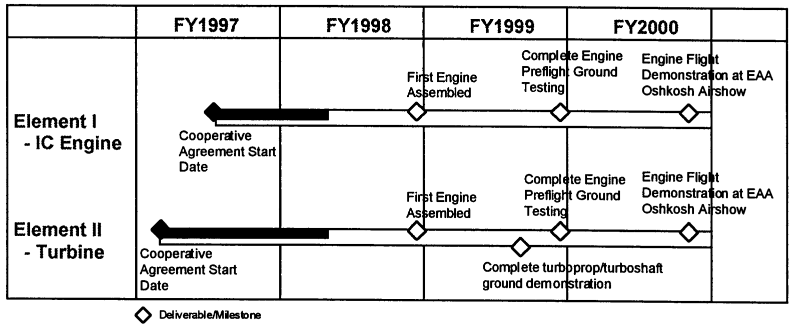
Element I - Partnership with Teledyne Continental Motors CPT to build and flight demonstrate an IC Engine


GAP IC

Element II - Partnership with Williams International CPT to build and flight demonstrate a Turbine Engine; and build and ground demonstrate a Turboshaft/Turboprop engine having a common core with the turbofan


FJX-2

GAP Project - Level 1 Schedule



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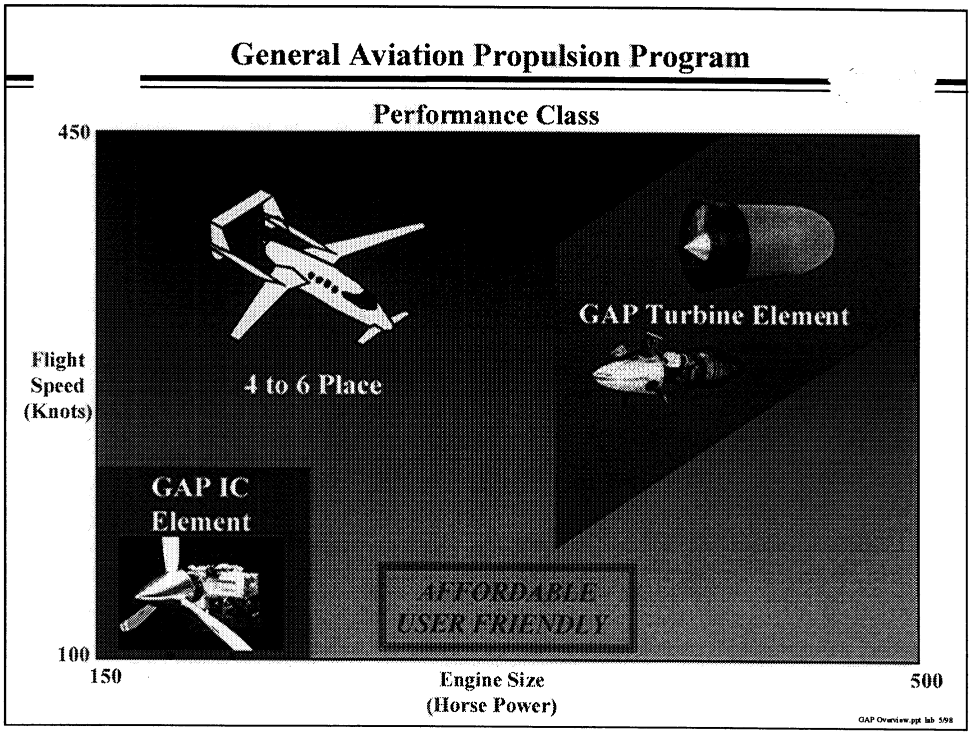
The GAP program is a four year program, begun in 1997, for which NASA has provided $55 million. Industry is making an equal investment in the program. GAP is divided into two Elements, the Intermittent Combustion (IC) Element and the Turbine Element. Each Element is implemented through a Cooperative Agreement with an industry led team. Each team will flight demonstrate its engine concept by the year 2000. The engine manufacturer on each team has committed to putting a new engine on the market, based on these engine concept demonstrators, within a couple of years after the completion of the GAP program.



The engine demonstrators being developed in GAP will cover both entry level aircraft and high performance aircraft. Commercial derivatives of these engines will be developed to cover the full spectrum of general aviation light aircraft applications.

General Aviation Propulsion Program

Engine Performance Goals

	IC	Turbine
Cost Reduction	50%	10^{-1}
Fuel	JP	
Ergonomic	Similar to Automotive Comfort, Ease of Use	
Maintenance Cost Reduction	50%	10^{-1}
Specific Fuel Consumption Reduction	25%	
Environmental Compliance		
- Emissions		
-- gaseous emissions reduction	Meet expected standards for year 2000+	Meet expected standards for year 2000+
-- particulate visibility	Meet expected standards for year 2000+	Meet expected standards for year 2000+
- Noise	Meet expected standards for year 2000+	Meet expected standards for year 2000+

The design goals which have been set for each Element are as follows:

IC Element

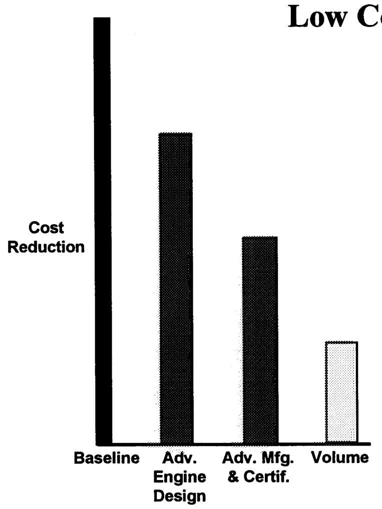
Reduce acquisition and maintenance costs by 50% compared to current engines. Avoid the use of leaded gasoline or any other environmentally dangerous fuel; use jet fuel if possible. Achieve propulsion related comfort and ease of use levels similar to those in the automotive world. Meet or exceed expected environmental regulations.

Turbine Element

The turbine engine already has the types of characteristics needed except for cost, so the major goal here is to reduce the acquisition and maintenance costs of small turbine engines by an order of magnitude while maintaining good performance levels. As with the IC Element the engine must meet or exceed expected environmental regulations.

General Aviation Propulsion Program

Low Cost Engine Strategy



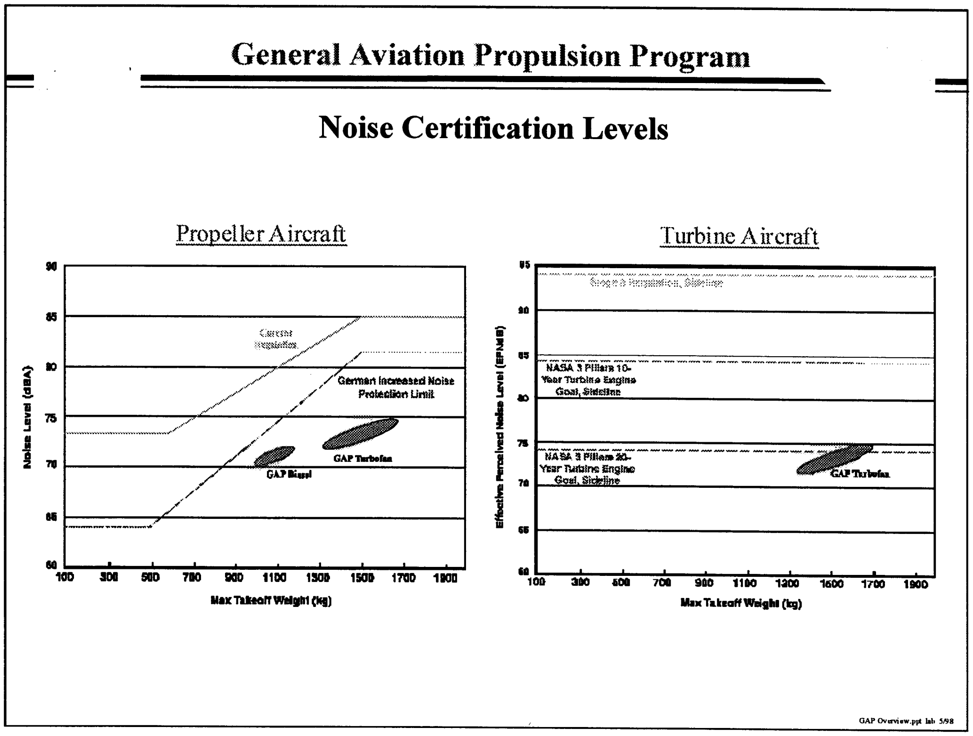
Advanced Engine (Keep it Simple):
- Common Core Approach
- Design Simplicity – Min. Components
- Concurrent Engineering – Simplified Assembly
- Avoid Exotic Materials
- Electronic Fuel Control
- Fast Prototyping

Advanced Manufacturing Methods:
- Near Net Forming
  - Precision Casting
  - Precision Stamping
  - Precision Extruding
  - Other Advanced Processes
- High Speed Machining
- Advanced Joining Methods
  - Laser Welding
  - HIP Diffusion Bonding
  - Inertia Welding
  - Other Advanced Methods

Certification
- **Early FAA Involvement**

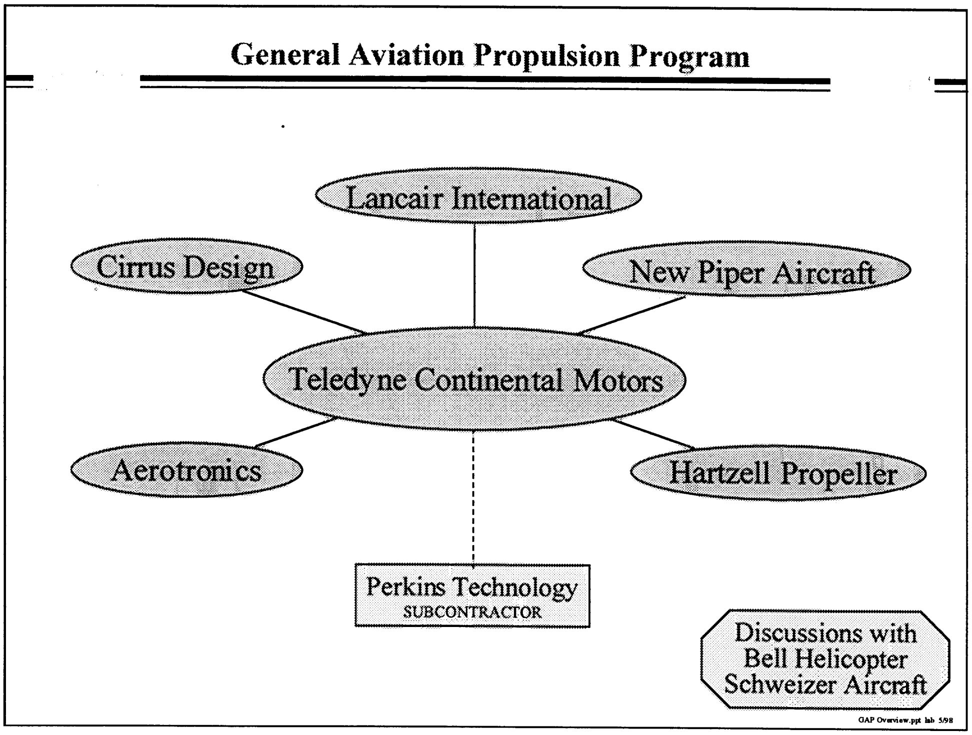
Production
- Volume

The approach to achieving low cost is three pronged. First, design the engine to be as simple and with as few parts as possible. Second, design the engine with ease of manufacture and assembly as a primary objective. Design for high volume manufacturing methods. Third, build a large market base by making the engines as versatile as possible to cover the widest number of applications. Develop non-traditional markets such as marine applications.



Aircraft powered by commercial derivatives of the GAP engines will be the quietest aircraft in the air, both for those on the ground and for the passengers. They will meet future noise regulations.

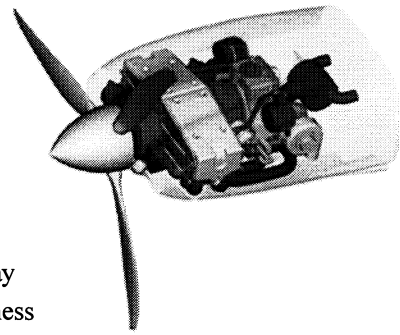
IC Engine Element



The NASA industry partner for the IC Element is a team headed by Teledyne Continental Motors (TCM). The team consists of three airframers, Cirrus Design, Lancair International and New Piper Aircraft, to ensure that the new engine and propulsion system will fit the needs of the airframe companies for new products and to allow integrated engine/aircraft system design at the earliest stages of development. Aerotronics is developing engine controls and displays. Hartzell Propeller is developing quiet propeller designs. Perkins Technology is subcontracted to TCM for detailed engine design and analysis. There have also been discussions with helicopter manufactures to ensure that their requirements are met.

General Aviation Propulsion Program

Teledyne Continental Motors CSD 283

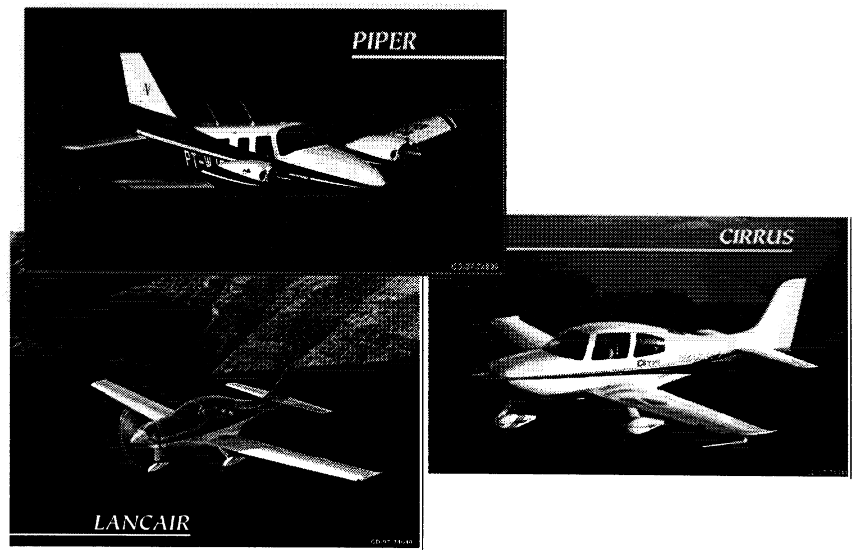


- Compression Ignition Engine
- 2 Stroke, Direct Injection
- Liquid Cooled
- 200-bhp @ 2200-rpm
- Jet Fuel
- Single Lever Power Control
- Electronic Diagnostics and Display
- Low Noise, Vibration and Harshness
- Meets Expected Future Emissions Requirements
- 1/2 Cost Current Engines

The engine being developed under the IC Element is a horizontally opposed, two stroke, compression ignition (diesel) engine which will run on jet fuel. Jet fuel is much more available world wide than gasoline and is much cheaper than gasoline in some areas. The demonstrator engine will be a 4 cylinder 200 horse power engine. It is designed to enable easy growth to 6 and 8 cylinder versions. It is a direct drive engine with a propeller shaft output speed of 2200 rpm. The reduction in output speed from the current 2700 rpm will facilitate a major reduction in propeller noise. One power lever will control the propulsion system including engine power and propeller pitch, there is no mixture control on a diesel engine. The engine will have a very low parts count and be designed for automated production methods to achieve a 50% reduction in cost.

General Aviation Propulsion Program

GAP IC Engine Demonstrator Aircraft



The GAP IC engine will be flight demonstrated at on three aircraft, the Cirrus SR20, the Lancair Columbia and the Piper Seneca IV.

General Aviation Propulsion Program

Turbine Engine Element

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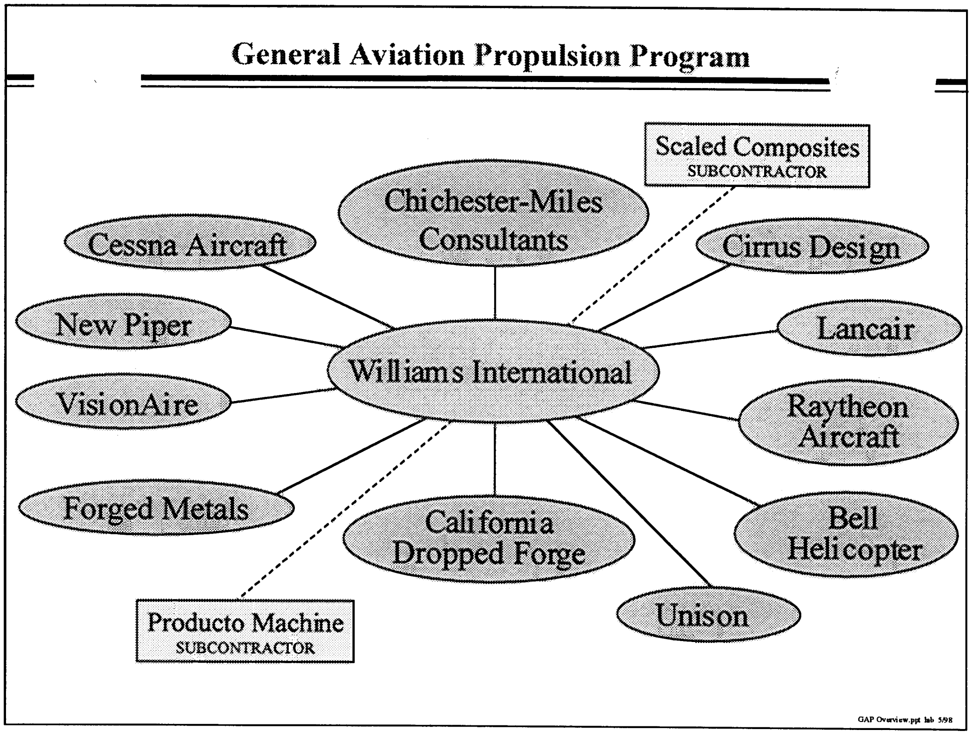
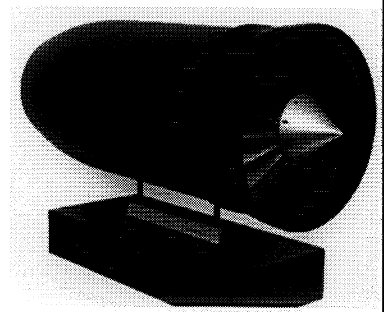


The NASA industry partner for the Turbine Element is a team headed by Williams International (WI). The team consists of seven airframers, Cessna Aircraft, Chichester-Miles Consultants, Cirrus Design, Lancair, New Piper Aircraft, Raytheon Aircraft and VisionAire, to ensure that the new engine and propulsion system will fit the needs of the airframe companies for new products and to allow integrated system design at the earliest stages of development. Unison is developing the engine ignition system. California Drop Forge and Forged Metals are working on low cost forging techniques. Producto Machine is subcontracted to WI to develop very precise low cost machining capabilities for small engine components. High precision is needed to maintain good performance capabilities in small engines. Scaled Composites is subcontracted to WI for final design, manufacture and flight testing of the V-Jet II demonstrator aircraft. A totally new aircraft is needed to fully demonstrate the aircraft design and performance capabilities which this engine will enable.

General Aviation Propulsion Program

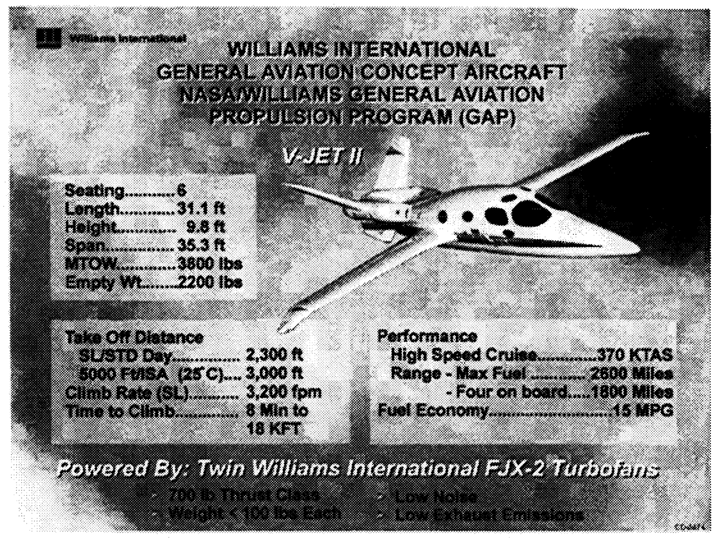
WILLIAMS INTERNATIONAL FJX-2



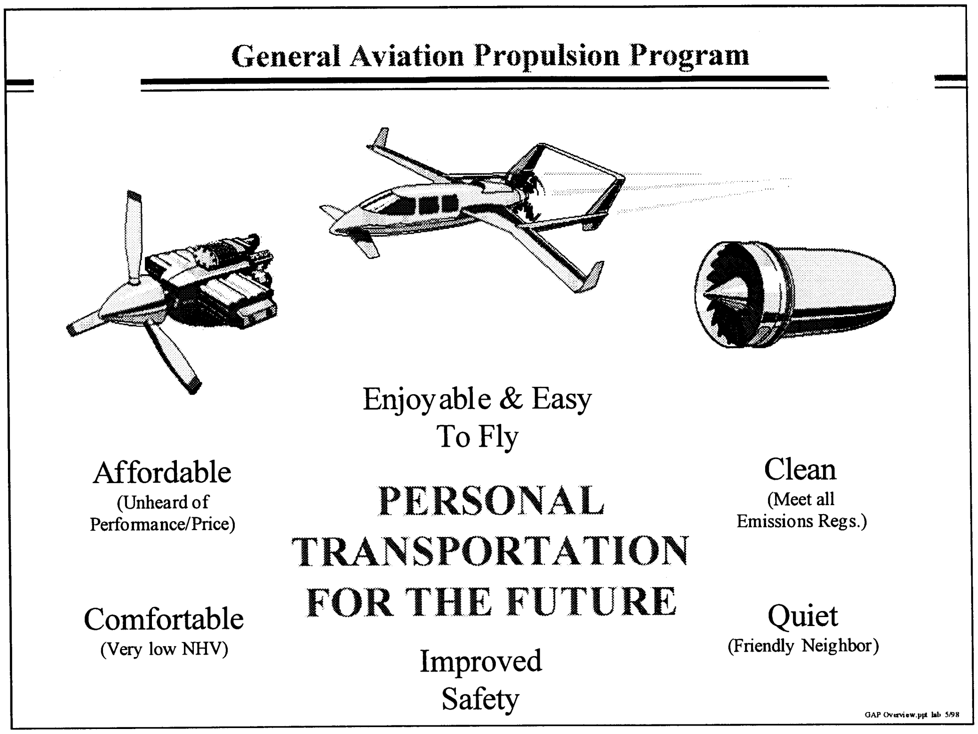
- Turbofan, Bypass Ratio of 4
- 700-lb Thrust Class with Growth Capability
- 14-inch Diameter by 41-inch Length
- Weighs less than 100 lbs.
- Jet Fuel
- Cost Competitive with Comparable Power Piston Engines of Today
- Single Lever Power Control
- "Take-off to Landing" Fuel Burn Less Than Comparable Piston Engine Power Airplane
- Meets Future Exhaust Emissions and Noise Requirements
- Common Core Design For Turboprop & Turboshaft Versions

The FJX-2 turbine engine is a high bypass turbofan with a "common core" design which will enable turboprop and turboshaft versions of the engine to be designed and produced. The engine design point is a bypass ratio of about 4 with 700 lbs. sea level static thrust and a weight of less than 100 lbs., giving it an excellent thrust to weight ratio. At reasonable production levels the engine should be cost competitive with current piston engines. When the weight, performance and installation advantages this engine provides are taken advantage of in an integrated aircraft design, the aircraft fuel burn for a given mission will be comparable to a piston engine powered airplane.

General Aviation Propulsion Program



The V-Jet II was conceptually designed by Dr. Sam Williams with final design and manufacture performed by Scaled Composites. The aircraft was specifically built to demonstrate the revolutionary type of general aviation light aircraft that the FJX-2 engine will enable. An old axiom is "new engines enable new aircraft" and that is certainly born out by the FJX-2 and the V-Jet II. A twin engine demonstrator aircraft was selected for safety purposes since this is a totally new engine being flown for the first time in a totally new aircraft. As seen in the chart the aircraft has excellent performance and weight characteristics. Although there is no intention to manufacture the aircraft, the V-Jet II was designed to be fully produceable with low cost manufacturing techniques and viable as a certified production aircraft so that there would be no doubt as to the potential that the FJX-2 introduces in to the general aviation light aircraft market. The aircraft was demonstrated for the first time at the Experimental Aircraft Association's Oshkosh'97 Fly-In Convention. The V-Jet II currently has FJX-1 interim engines installed which do not allow it to meet its full performance potential or fuel consumption goals, but do allow the aircraft to be checked throughout most of its flight envelope before the FJX-2 engine is ready.



Coming soon, with the completion of the GAP and AGATE programs, are light general aviation aircraft that are fun and easy to fly. They will be affordable, comfortable and allow general aviation to be a friendly neighbor. We will have the makings of a true personal transportation system which everyone can enjoy!